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(54) APPARATUS FOR PROVIDING INFORMATION RELATING TO THE FLOW OF A FLUID

(71) We, PURITAN-BENNETT CORPORATION, a Corporation organised under the laws of the State of Delaware, United States of America, of 10845 Baur Boulevard, St. Louis, Missouri, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to apparatus for providing information relating to the flow of a fluid. More particularly, but not exclusively, the invention relates to instrumentation for pulmonary diagnosis, and especially pertains to a breath transducer functioning under the force of specimen breath to provide lineal displacement of a diaphragm for allowing diagnosis of the patient's lungs and a possible detecting of early signs of pulmonary disorders.

Various types of pulmonary diagnostic instruments have long been available upon the market for use as a means for broadly testing for respiratory disfunction of persons who are believed to have some form of respiratory impairment. Instrumentation of this nature appears to be one means available to the medical profession as a means for detecting such disorders, since any such disease or obstruction somewhere within the remote confines of the lung are difficult of detection, do not provide any form of direct manifestation of existence, and io not lend themselves to any form of probe for direct analysis, and hence, such difficulty of detection originally led to the various forms of tests that could be conducted upon the respired breath as a means for sensing an indication of what perhaps might be a lung disfunction.

Any analysis of lung disease, heretofore, in this manner, for those forms of disease which lead to chronic airway obstruction, is generally recognized by the by the profession as one of the most important and yet frustrating health problems in existence, with the treatment of such diseases being particularly frustrating because by the time the patient usually seeks medical assistance, such as due to the physical manifestation of his shortness of breath or because some form of diagnostic test has finally revealed an abnormal pulmonary function, the disease is generally to that stage of development that it has become incurable. Part of this problem is due to the fact that present pulmonary diagnostic instruments are not sufficiently sensitive enough to provide an early warning of incipient diseases of the lung, but rather, such present instrumentation exhibit a rather wide variance of tolerance limits in their measurements that are really of very little assistance to the practitioners in their attempts to practice preventative type medicine for at least an early curtailment of any beginning lung disease.

Reportedly, among the most useful of pulmonary examinations that is currently receiving some attention as a means for detecting potential or developing disease of the lungs is the measurement for closing volume of the lungs during functioning of one's respiratory system. Closing volume has generally been thought to be a measurement which may perhaps detect respiratory disease in its preclinical stages. It is the lung volume during expiration when emptying of the dependent regions of the lung is severely reduced or ceases all together. A certain amount of closing volume exists in most individuals, with the capacity for closing volume gradually increasing with age, a phenomenon that is thought to exist and occur due to the changes in the lung elastic recoil over a lifetime. Hence, certain standardized forms of information are available regarding closing volume, and which can and do establish the health parameters for individuals with normal pulmonary functioning. On the other hand, persons that have either definite lung disease, or those that subject themselves to excessive tobacco smoking, exhibit changes generally of detrimental form in the measurement of their closing volumes which may give a ready indication that airway obstruction is developing or has long developed, and perhaps is amplifying to dangerous levels, so that the physician know that

disease is present and a medical reality in the lungs.

Medical authors have expressed the opinion that existing pulmonary devices are not accurate enough to provide the type of information that is needed for diagnosis of early airway diseases, but state that if such tests could be conducted upon instrumentation that would function with sufficient sensitivity and precision, then perhaps lung related diseases could be detected at their much earlier stages of development and lead to much more effective if not preventative treatment. Hence, sensitive instrumentation would be useful to provide patient pulmonary analysis on a much more great scale, and could even be used as a screening program for testing whole masses of people, and through the utilization of such sensitive test results, and their comparison with known health parameters, provide the medical examiner with sufficient information for determining whether any one individual tested may possibly be developing incipient lung and airway disease. Hence, such sensitive tests, including closing volume, could probably detect early lung damage, and possibly at a stage when it is still totally reversible.

Various types of pulmonary devices are presently available upon the market, and generally operate under a variety of principles to achieve breath analysis for determining, particularly, the closing volume of the lung in addition to other pertinent information. Such devices, as previously analyzed, have been of questionable accuracy, but in any event, they generally incorporate various types of spirometric instrumentation for analyzing the air respiring from the lungs. Such tests, more specifically, may provide an analysis of the nitrogen washout, including closing volume, vital capacity, and other lung air flow volumes of breath, and the information obtained from these tests is useful for providing some basis for medical analysis of the patient. Such devices may include the Expirometer as presently marketed by the Warren E. Collins, Inc., of Braintree, Massachusetts. The spirometer functions under the principle of rotating turbine blade means to reflect a light on a photo-transistor for producing pulses that are counted by digital logic for yielding a direct volume readout of pulmonary flow rate. The Spirostat is a turbinometer, having bi-directional measuring attributes, and which measures the rotational speed of turbine-like vanes which is proportional to the flow of the specimen breath. This device is manufactured and marketed by Fibre-O-Optics Industries, Inc., of West Palm Beach, Florida. Other forms of prior art pulmonary analyzing devices include the Pulmonary Functioning Indicator, as manufactured and sold by Chemetron Corporation, of Chicago, Illinois, and the Pulmonary Function Analyzer, as marketed by the Monaghan Company of Denver, Colorado. Both of these two latter devices incorporate a thermistor, either of the hot wire type or the trimetallic bead type, which when cooled by expired breath provides a read out of information relating to lung volume and breath flow.

The problems with many of these prior art spirometers are accurately described in the New England Journal of Medicine, Volume 289, No. 24, commencing on page 1283, and entitled "Evaluation of Electronic Spirometers", by FitzGerald, Smith, and Gaensler. For example, in a test using the Spirometer for determining maximum voluntary ventilation, the subject instrument underestimated this measurement on the average of forty-four percent. The Pulmonary Function Analyzer underestimated by twenty-one percent the true measurement for maximum voluntary ventilation during the instrument evaluation. In their evaluation of these instruments for their effectiveness in measuring the forced vital capacity of the subjects being tested, the Pulmonary Function Indicator recorded volumes that were twenty to fifty percent high. The Spirostat recorded accurate volumes only at rapid flow rates, but that when its syringe emptying time exceeded two seconds, the volume in one second test, the Pulmonary Function Indicator showed almost random scatter of measurements, with values deviating from the expected by as much as plus forty percent to minus eighty-five percent. In forced vital capacity tests, the Expirometer recorded readings as much as sixteen percent over what the reading should have been, and it was determined that this occurs in the turbine-comprising type of instrument due to the inability of the turbine means to quickly change their velocity during uneven breath flow type tests.

Such deviations in measurements of pulmonary function provide information that certainly cannot be utilized by the practitioner with sufficient confidence as a means for determining the presence of pulmonary disease, particularly at an early stage. As the authors state in the aforesaid article: "The increasing prevalence of chronic obstruction lung disease underlines the importance of screening of ventilatory function in the physician's office, in the clinic, and at the bedside". But unless the present instruments ". . . are accurate and stable in the clinical context their general use may prove misleading in individual cases and eventually may discredit screening procedures of proved value". They summarize that the permissible range of deviation of plus or minus five percent from the primary standard is needed to observe the course of disease or the effect of drugs in an individual patient. "Electronic

spirometers offer sufficient convenience advantages to justify further development. The instruments that we examined would not be recommended in their present form because of insufficient accuracy and because three lacked facilities for calibration. Furthermore, convenience advantages are offset by high cost and lack of permanent record without expensive accessory equipment."

One other instrument is presently and commonly used for measuring the velocity of respiratory air currents. This device is entitled the Pheumotachograph, and is sold by Instrumentation Associates of New York, New York. This device operates upon the principle of passing the breath through a plurality of small diameter ducts, being approximately 0.8 mm. in diameter and 32 mm. in length. The instrument then measures the pressure differential between the air entering the series of ducts, and that leaving said ducts, and the measurement of this pressure drop providing a reading as to the representative velocity of expired breath. One advantage of utilizing this type of a pressure drop or differential measurement is that it is much more responsive instantaneously to the exact quantity and velocity of the passing breath, but one draw back is that it is difficult to control the conversion of such measurements to representative values of breath flow so as to provide accuracy in read out, and this is due mainly because there is no physical manifestation of this pressure differential that can be easily detected and gauged by supporting mechanism. In addition, this prior art instrument is quite elaborate of structure, and expensive of cost.

Hence, in view of the foregoing, effectiveness, accuracy, and reliability of diagnostic equipment is just as important to patient welfare as the effectiveness, precise dosage, and purity of administered drugs. The need for instrumentation to provide accurate pulmonary diagnosis is readily apparent from the measurements and testing that has been made upon existing prior art devices.

In accordance with the present invention, there is provided apparatus for providing information relating to the flow of a fluid, the apparatus comprising: a flow tube; a plate disposed in the tube so as to allow the flow of the fluid through the tube, the plate being lineally and completely displaceable by the flow of the fluid through the tube; a plurality of resilient arcuate arms each connected at one end to the periphery of the plate, the other ends of the arms being secured within the flow tube, the arms supporting the plate and allowing the plate to be lineally and completely displaced by the flow of fluid through the tube; and means for detecting the degree of lineal displacement of the plate.

Apparatus in accordance with the invention is particularly useful for detecting lung disfunction through specimen breathing, the detected degree of lineal displacement of the diaphragm providing representative information pertaining to pulmonary function for specimen diagnosis. The invention is hereinafter described in relation to this use.

This invention contemplates the use of a suspended sensitive partial diaphragm comprising the plate which the plate upon encountering the flow of breath enters into a degree of lineal displacement which is detectable and measurable to provide readings that can be electronically converted to furnish direct information relating to the functioning of the pulmonary system of a patient. Such information, as previously analyzed, and if of sensitive scope, can provide the physician with needed information for determining early signs of lung disease. As also previously analyzed, prior art devices of this nature are too insensitive and exhibit too great a tolerance for error, and therefore, can only be used in general screening tests of large numbers of people as a means for only detecting disease when it has become a major detriment to the patient itself, and in most cases has already reached the irreversible stage. Heretofore, various types of prior art breath analyzers have established the normals and averages for pulmonary functions for great masses of patients and populations, with said information having been derived over long periods of time. These measurements have led to the charting of classical parameters that provide understandable information regarding normal and properly functioning pulmonary systems for healthy individuals. In addition, the present invention can also be used to provide further accuracy in these established averages, and to refine them to the point where the normals for pulmonary systems of healthy individuals can be accurately plotted and charted, and then when a potentially diseased lung of a test patient is detected by comparing the latter's test results to the predicted, any divergence can be used to determine the degree of normalcy of the patient, with the discrepancy from the normal providing the physician with more sensitive information that can be analyzed for discerning just where the incipient disease may be germinating.

The present invention lends itself well to the accurate measuring of both the closing volume and nitrogen content of the pulmonary system, and is also adaptable for making other measurements in the category of vital capacity and forced vital capacity, in addition to related respiratory tests.

The invention utilizes the teachings of Poiseuille's law, wherein the velocity of a flow of a fluid through a tube varies directly

with the pressure and the diameter of the tube and inversely with the tube length and fluid viscosity. This invention utilizes an additional element by including a suspended diaphragm in the path of breath flow, and subjecting its physical displacement to accurate detection for a determination of vital information pertaining to lung capacity and function.

The partial diaphragm of this invention may comprise a foraminous like screen that is suspended within the interior of a flow tube, and which screen can be deflected by the movement of the patient breath therethrough, which lineal deflection may be in the vicinity of one hundred thousandths of an inch, more or less. In the preferred embodiment, the screen further incorporates ferromagnetic means, such as rings, that may be mounted peripherally of the screen and designed for deflecting in unison with said suspended screen. An electrical detecting means, such as a wound core, but more specifically an E-core, may be packaged within a housing through which the flow tube or transducer may be insertably mounted, and which core, as in the case of the E-core, may incorporate a pair of coils, with one of each coils being arranged spatially to either side of the screen and its rings for equalization in the flow of the magnetic lines of flux generated by the core. Movement of the foraminous screen one way or the other longitudinally of the tube provides a type of lineal displacement that disrupts equality and the continuity of flow of the lines of flux around the core, and through the use of any standard form of electrical detecting means the imbalance in the generated inductance may be readily detected, electronically measured, amplified, converted, and readout as a direct reading for indicating the flow, volume and other pertinent information pertaining to the breath being respired.

While the foregoing described transducer contemplates a form of peripherally suspended diaphragm within the flow tube, such as through the use of a series of arcuate arms which may extend the distance between both the foraminous plate and the wall of the flow tube, other forms of diaphragm mounts, such as center mounts, may be used for likewise suspending the screen in a quasi-free manner so that it will be directly influenced and lineally deflected by the passage of breath. Such center forms of mounts may include a pair of diametral supports spaced to either side of the screen, mountetd within the flow tube a fixed distance apart longitudinally of the flow tube, and incorporate rod means to which the resilient arcuate arms are secured. When breath is forced through the flow tube as during specimen tests, such a plate is free for detectable displacement for providing measurements of medical value to the physician or technician analyzing the pulmonary system of the subject patient.

In addition, various forms of capacitive plate detecting means may be utilized for determining the degree of displacement of the partial diaphragm, and provide a source of measurements that can be converted into pulmonary function information. Such capacitive means may include a pair of capacitor plates, one mountetd spatially to either side of the diaphragm, and in cooperation with similar type plates mounted to the diaphragm itself, providing for a direct reading of the capacitive imbalance as lineal displacement due to the force of the passing breath occurs. Once again, any type of standard electrical circuitry may be used for detecting this variation in capacitance, and through simple computation or computer means converting such readings to information regarding lung functioning.

The breath transducer of this invention may include other means for facilitating the quick insertion of the flow tube into its holder, including an indexing tab that provides for proper positioning of said tube, in addition to an annulus that limits the extent of insertion of the flow tube into said holder. Obviously any insertion limiting means is necessary to provide for accuracy in the readout from usage of one flow tube to the next, since the positioning of the E-core, capacitor plates, or any other form of lineal detecting means that measures the degree of displacement of the diaphragm must operate consistently from transducer to transducer.

The invention is further described below by way of example with reference to the accompanying drawings, wherein:

Figure 1 provides a perspective view of a breath transducer of this invention shown inserted within its holder;

Figure 2 presents a front end view of the instrument as shown in Figure 1;

Figure 3 provides a side view of the instrument shown in Figure 1;

Figure 4 provides a longitudinal sectional view taken along the line 4—4 of Figure 2, showing a cross section of the breath transducer and its holder.

Figure 5 provides an exploded view of the breath transducer showing its feature to separate as during installation of the diaphragm during manufacture;

Figure 6 provides an end view showing the mouth piece portion of the breath transducer of this invention;

Figure 7 provides a side longitudinal view of the breath transducer of this invention;

Figure 8 provides a transverse section taken along the line 8—8 of Figure 7, showing the diaphragm mounted within the transducer flow tube;

Figure 9 provides a side view of a modified form of breath transducer, showing in

the cutaway portion another form of suspension means for the diaphragm of this invention;

Figure 10 provides a transverse section taken along the line 10—10 of Figure 9, showing the modified form of diaphragm and suspension means of its transducer; and

Figure 11 provides a longitudinal view of the transducer of this invention showing the form of capacitive detecting means for gauging diaphragm displacement.

In referring to the drawings, and in particular Figure 1, there is disclosed the transducer or flow tube 1 of this invention shown mounted by insertion within the housing 2, thereby providing a convenient combination of components that may be easily handled by both the physician and the patient for achieving breath analysis. The transducer 1 may be constructed of any form of polymer, although a transparent material such as poly(methyl methacrylate) has been found to be of advantage. In addition, the housing may be constructed of any form of polymer of other material which lends itself to frequent use and handling, while yet maintaining an appearance that is consistent with professional usage. The housing 2 is formed having an upper segment 3 through which is provided longitudinally a series of apertures and through which the transducer 1 may insert, while the lower segment 4 of the housing has smooth curvature flared laterally to facilitate its hand grasping and retention, while interiorly providing ample space for mounting of the various electrical and electronic instrumentalities useful primarily as the means for detecting the functioning of the transducer during usage.

By referring also to Figures 2 and 3, it can be seen that the transducer desirably has sufficient length to provide for its projection from both ends of the housing, but that proximate its one end it is formed to provide the mouthpiece 5 which is normally disposed for oral grasping by the patient, as during pulmonary testing. An annulus 6 is formed integrally with the flow tube, being spaced a slight distance from its one end to form a limit to the length of the mouthpiece 5, while said annulus also circumscribes the depth of insertion of the flow tube into the housing upon its encountering a proximate wall of the upper segment 3 of the housing.

By referring also to Figure 4, in addition to Figure 2, it can be seen that the transducer 1 includes an indexing means 7, which is in the nature of an integral tab formed upon the surface of the flow tube, with said tab disposed for close contact insertion within a slot 8 formed through the front wall of the housing segment 3, and in this manner provides a means for insuring that the transducer is properly positioned for accurate usage in the housing 2. The front end 9 of the index tab 7 is conveniently tapered to facilitate its initial insertion into the said housing and its formed slot 8.

As further seen in Figure 4, the housing 2 is formed into its two sections 3 and 4, as previously described, and may include an intermediate wall 10 for segregating the transducer mounting space, as in the section 3, from the electronic packaging space 11, as provided in the bottom section 4 of the housing. As shown within the interior of this lower section 4 of the housing, the electronic package, which may include the usual circuit board and other solid state or other form of electronic devices may be conveniently mounted, as at 12, to the underside of the partition 10, or may be located at any other convenient position within said lower section 4. The usual conduit 13 may insert through one end of the section 4 for communication with the electrical package 12, and provide necessary connection thereto. Where the transducer is to be utilized for testing other than the lung dead space component or for their closing volume, as for example in the standard nitrogen washout form of other test, then additional instrumentalities customarily used for this latter type of a test may be disposed within this lower section 4 of the housing, and also communicate exteriorly of the same as through the conduit 13 or others. Where the instrument is to be utilized for this type of a test, an aperture 14 may be provided through the wall of the flow tube 1 to provide the location where the nitrogen laden breath may be exhaled for eventual confinement and measuring of its nitrogen content.

As can further be seen in Figure 4, a form of diaphragm 15 is suspended within the flow tube of the transducer, and as previously summarized and hereinafter described, is subject to lineal displacement due to the force and pressure of the moving breath there past. One means for detecting this degree of displacement of the diaphragm may comprise a form of electrical core 16, which is precisely mounted to the intermediate wall 10 of the lower section 4 of the housing, and disposed generally equidistant to either side of the transducer diaphragm 15. In this particular instance, the core may comprise an E-core, having a pair of electrically conductive coils 17 and 18 provided thereon, and to which may be applied a reference potential for the purpose of inducing the transfer of the magnetic lines of the flux on a path through the various proximate segments of the E-core, in addition to the surrounding environment, particularly above the core, and within the influence of the said diaphragm. Generally, and in the preferred embodiment, a reference potential within the vicinity of 10 volts, peak to peak, and of about 5KHz frequency has been found useful

for this purpose, although other ranges of voltages and frequencies may be useful to provide the same function. As is well known in the art, any form of electrical detecting means for determining the degree of imbalance of the inductances in the two segments of the core may be used for detecting the alternating current output of the core, and which output may be rectified and filtered to provide a direct current output signal that is directly proportional to the displacement of the diaphragm. Obviously this can be correlated to provide a direct readout of the rate of flow and other characteristics of the sample breath, and can be electronically computed and converted into readings for furnishing a direct observation of these results.

The preferred style of transducer is shown in Figures 5 to 7, wherein the flow tube 1 is shown as being separable into two sections 19 and 20, the site of the separation being approximately where the diaphragm 15 is mounted therein, so as to facilitate the manufacture of this device. As shown, one end section of the separated flow tube may have a reduced lip 21 that may insert within the mating end 22 of the other tube section, and in this manner provides means for embracing the periphery of the diaphragm 15 therein, with said tube then being adhesively or otherwise secured together to form an integral transducer. Obviously, though, a separable tube is not the only manner for mounting a diaphragm therein.

As previously described, the annulus 6, which acts as a stop means to limit the extent of insertion of the flow tube into its housing, and the inner tab 7, are provided integrally upon the flow tube to regulate its precise positioning within the housing, as during usage.

The diaphragm 15 is more accurately shown in Figure 8, and is formed as an apertured plate 23 useful for partially impeding the flow of breath therethrough so as to induce a slight pressure drop and the incident lineal displacement of the plate under the force of pressure of the breath. This plate may be formed of any type of material that may be reasonably precise and consistent in this degree of displacement with respect to the pressure of the breath it is subjected to, but preferably the plate is constructed of a beryllium copper or perhaps stainless steel, and chemically etched to form uniform apertures therethrough. Preferably the plate has 200 to 500 mesh openings per square inch. Hence, the completed plate has the appearance of a foraminous screen, which is milled to those precise tolerances so as to provide consistent readout of information under identical test conditions. The foraminous plate 23 has integrally formed therewith, as around its periphery, a series of resilient arcuate shaped arms, the three arms 24 to 26 in this particular design, which integrally connect to the plate at one end, as for example as seen at 27, while at their opposite ends, as as 28, they integrally connect with a circumferential ring 29 which is mounted to the interior surface of the flow tube, as for example as previously described with respect to the intermating of the end sections 21 and 22 of the flow tube. On the other hand, many other means for adhesively mounting or adhering the circumferential ring 29 within the flow tube should be readily apparent. Due to the arcuateness of the arms 24 to 26, it can be seen that the apertured plate 23 is capable of some displacement as pressure is applied to it, which in this particular instance is normally the pressure of the patient's breath, this deflection sometimes achieving a displacement of approximately one hundred thousandths of an inch, an amount which is easily detectable and measurable by the type of previously described electrical pickup and detecting means.

Surrounding the periphery of the apertured plate 23 are a pair of rings, as at 30 and 31, and these rings are secured to the plate at this location by any form of weld or adhesive, and preferably are constructed of ferrous material that provides a more conductive path for transfer of the magnetic lines of flux generated in the E-core. As can be seen, one such ring is mounted to either side of the foraminous plate, and when this partial diaphragm of the transducer is located at the approximate midpoint of the detecting means core, there is provided a balanced relationship between the core inductances indicating a static condition for a null reading. On the other hand, when breath is forced through the transducer and displaces lineally the diaphragm 15, it can be seen that said diaphragm will be slightly urged in the direction of breath flow, thereby creating a more conductive path for the lines of flux to flow with respect to one end of the E-core than the other, thereby creating an inductance imbalance which is detectable by the usual electrical circuit means, such as from a center tab associated with the core, as is known in the art. This form of diaphragm may be described as a peripherally mounted displaceable diaphragm.

As seen in Figures 9 and 10, a modified form of the lineal displaceable diaphragm of this invention is shown, and this type of diaphragm is depicted as a centermount form of suspension for the lineally displaceable diaphragm. As shown, the transducer or flow tube 32 has formed integrally therein a pair of spaced apart diametral supports 33 and 34, and which includes a rod member 35 which connects with and spans the longitudinal distance between said two sup-

ports. The partial diaphragm 36 is constructed as the type of foraminous screen or plate as previously analyzed with respect to the peripherally mounted diaphragm, but having the rod 35 extending therethrough, and around the periphery of this plate 36 is provided at least one annulus or ring 37. This ring is constructed preferably of a ferromagnetic material, and functions similarly to the pair of rings 30 and 31 as previously described with respect to Figure 7. Connecting between the annulus 37 and the rod member 35 are a series of resilient arcuately shaped arms 38, in this particular instance being three arms, with said arms at their outer ends being secured to the annulus 37, while their inner ends are secured to the rod member 35. Hence, it can be seen that the force of breath flowing through the flow tube 31 will encountetr the foraminous plate 36 and cause its displacement. Since this transducer is constructed to the same dimensions that provides for its ease of insertion and location within the housing 2, as previously described, the degree of displacement of the foraminous plate or diaphragm 36 can be gauged by any form of detecting means, such as the E-core as previously described.

A final modification or variation upon a type of partial diaphragm and detecting means is shown in Figure 11. In this embodiment, the transducer or flow tube 48 may incorporated the type of peripherally mounted diaphragm 49 which may be constructed identical with the diaphragm and suspension means 15 as previously analyzed, although the centre mount form of suspended diaphragm may also be used in this modified embodiment. In this particular instance, the pair of rings 50 and 51 secure proximate the periphery of the foraminous plate of the diaphragm and function as capacitive plates, and each ring is spaced normally a fixed distance from corresponding capacitive plates 52 and 53 which are also secured rigidly to either the interior of the flow tube, as shown in the drawing, or even can be permanently mounted to the housing and disposed for accommodation of the flow tube therethrough. Actually, these capacitive plates 52 and 53 are also constructed in the form of rings. Hence, a charge, as from a battery or other electrical source 54, provides for charging of the respective pairs of plates 50 and 52, and 51 and 53, so that when the diaphragm 46 is maintained stationary an equal distance between the two plates 52 and 53, there will be no capacitive imbalance that is detectable of any measurement. On the other hand, as specimen breath flows through the transducer, thereby causing the diaphragm 49 to lineally displace, its associated capacitive rings 50 and 51 are likewise displaced providing for this capacitive imbalance being detected, measured, and amplified, as at 54, to provide a readout of information corresponding to the flow of the patient's breath.

It should also be obvious that the principles of this invention can be adapted for use in detecting information about fluid or gas flow in industrial processes.

The foregoing provides a description generally of various types of sensitive means for analyzing breath flow particularly through the lineal displacement of a diaphragm along the longitudinal length of a transducer, which detected information can be converted for readout of pulmonary function information. Such information can be analyzed by the physician or technician as an indicator of early warning of lung disease. Furthermore, the integral formation of the transducer of this invention, apart from the detecting means, allows its once use and then disposal. Such provides great sanitation in the use of this medical instrument. In addition the detecting means may be optically operative, such as through the use of light sensitive diodes, and detect the displacement of the diphragm in this manner.

WHAT WE CLAIM IS:—

1. Apparatus for providing information relating to the flow of a fluid, the apparatus comprising: a flow tube; a plate disposed in the tube so as to allow the flow of the fluid through the tube, the plate being lineally and completely displaceable by the flow of the fluid through the tube; a plurality of resilient arcuate arms each connected at one end to the periphery of the plate, the other ends of the arms being secured within the flow tube, the arms supporting the plate and allowing the plate to be lineally and completely displaced by the flow of fluid through the tube; and means for detecting the degree of lineal displacement of the plate.

2. An apparatus according to Claim 1, wherein the plate is apertured to allow the passage of the fluid therethrough.

3. An apparatus according to Claim 2, wherein there are a plurality of apertures provided through the plate.

4. An apparatus according to Claim 2, wherein the apertured plate comprises a foraminous plate.

5. An apparatus according to Claim 4, wherein the foraminous plate comprises a screen.

6. An apparatus according to Claim 5, wherein the foraminous plate is constructed of beryllium copper.

7. An apparatus according to Claim 5, wherein the foraminous plate is constructed of stainless steel.

8. An apparatus according to any preceding claim, including a pair of rings, one ring being secured to each side of the plate for cooperating with the detecting means for

determining the degree of lineal displacement of the plate during the passage of the fluid therethrough.

9. An apparatus according to Claim 8, wherein the rings are mounted around the periphery of the apertured plate.

10. An apparatus according to Claim 8 or 9, wherein the rings are made of ferrous material.

11. An apparatus according to any preceding claim, wherein the resilient arcuate arms connect the plate with the wall of the flow tube.

12. An apparatus according to any preceding claim, wherein the arcuate arms are integral with the apertured plate.

13. An apparatus according to any preceding claim, wherein the arcuate arms are three in number.

14. An apparatus according to any preceding claim, wherein the flow tube is separable proximate the location of the apertured plate therein, thereby facilitating the mounting of the plate during manufacture.

15. An apparatus according to any of Claims 1 to 10, wherein said other ends of the arms are secured centrally within the flow tube.

16. An apparatus according to Claim 15, wherein a pair of supports are disposed diametrically across the interior of the tube and are spaced from each other a fixed distance, a rod extends between and connects the supports, the rod extends centrally through the plate, at least one annulus is connected to the periphery of the plate in proximity with the inner surface of the flow tube, and the resilient arms interconnecting between the annulus and the rod member.

17. An apparatus according to any preceding claim, including a housing provided for accommodating the flow tube, the housing providing means for facilitating its retention, the housing having a passage therein through which the flow tube removably inserts, the housing containing the detecting means for co-operating with the tube for determining the degree of lineal displacement of the plate.

18. An apparatus according to any preceding claim, wherein the detecting means comprises an electrically operative means.

19. An apparatus according to any of Claims 1 to 17, wherein the detecting means comprises an optically operative means.

20. An apparatus according to Claim 18 as appendant to Claim 8, wherein the rings are made of magnetic flux transferring material, the detecting means comprising a core and at least one associated coil capable of conducting an electric current, the displacement of the plate and rings influencing the inductance resulting from the current flow in the coil.

21. An apparatus according to Claim 18 as appendant to Claim 16, wherein the annulus is made of magnetic flux transferring material, the detecting means comprising a core and at least one associated coil capable of conducting an electrical current therethrough, the displacement of the plate and annulus influencing the inductance resulting from the current flow in the coil.

22. An apparatus according to Claim 20 or 21, wherein the core comprises an E-core having a pair of coils provided therein with each coil capable of conducting a current therethrough, the passage of the generated inductances resulting from the change in each coil being influenced by the displacement and location of the plate.

23. An apparatus according to Claim 17 or any of Claims 18 to 22, as appendant thereto, including stop means provided upon the flow tube and cooperating with the housing to limit the extent of tube insertion therein.

24. An apparatus according to claim 23, wherein the stop means comprises an annulus formed integrally upon the flow tube and provided for encountering a side of the housing to limit the extent of tube insertion therein.

25. An apparatus according to Claim 24, including a guide means provided upon the flow tube and cooperating with the housing to provide proper positioning of the tube when being inserted into the housing.

26. An apparatus according to Claim 25, wherein the guide means comprises an index tab integrally connecting and extending partially along the length of the tube and cooperating with a slot formed in the housing for proper positioning of the flow tube in the same.

27. An apparatus according to any preceding claim, wherein the detecting means comprises electrically operative means, the plate having a first capacitive means mounted thereto and provided for displacing therewith, a pair of additional capacitive means mounted within the flow tube and provided normally a fixed distance from the first capacitive means, and means for detecting the capacitive imbalance upon displacement of the first capacitive means and its apertured plate during passage of the fluid therethrough.

28. Apparatus according to Claim 1, substantially as described herein with reference to and as illustrated in Figures 1 to 8, Figures 1 to 8 as modified by Figures 9 and 10 or Figures 1 to 8 as modified by Figure 11 of the accompanying drawings.

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5 SHEETS

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.
SHEET 1

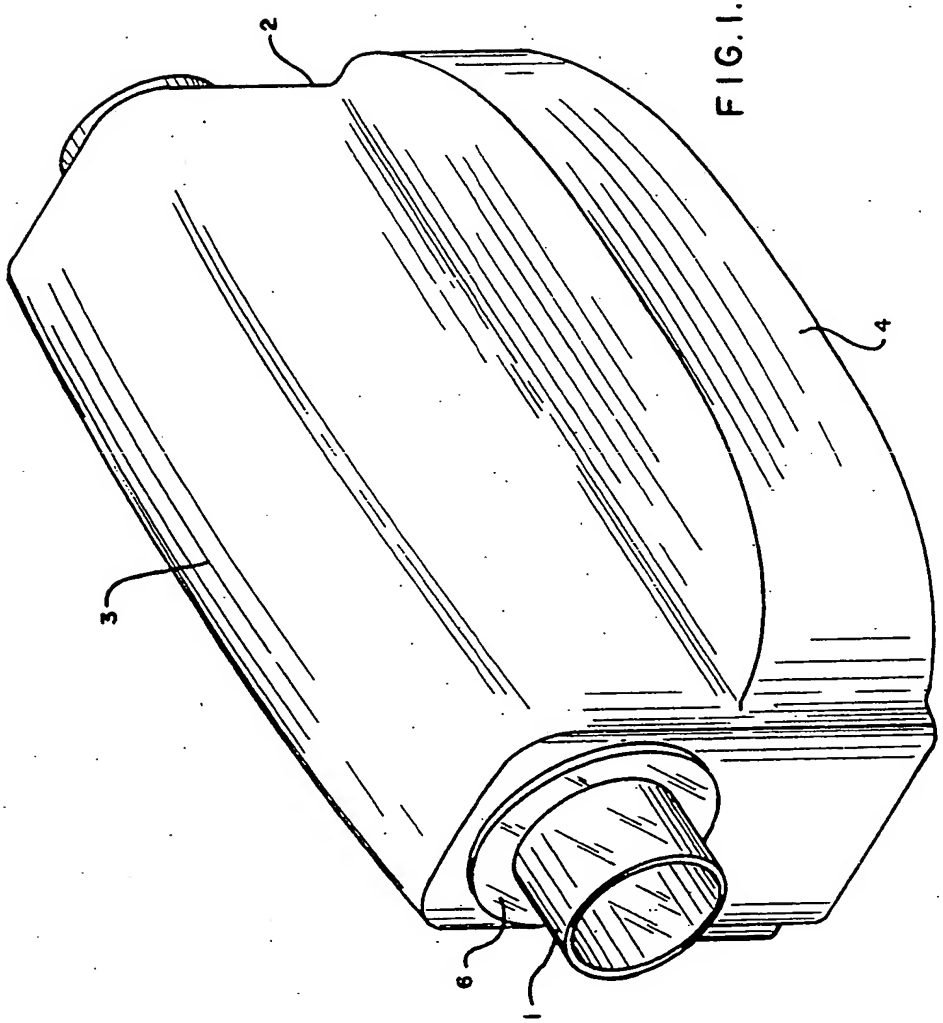

FIG. 1.

1 520432 COMPLETE SPECIFICATION
5 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEET 2

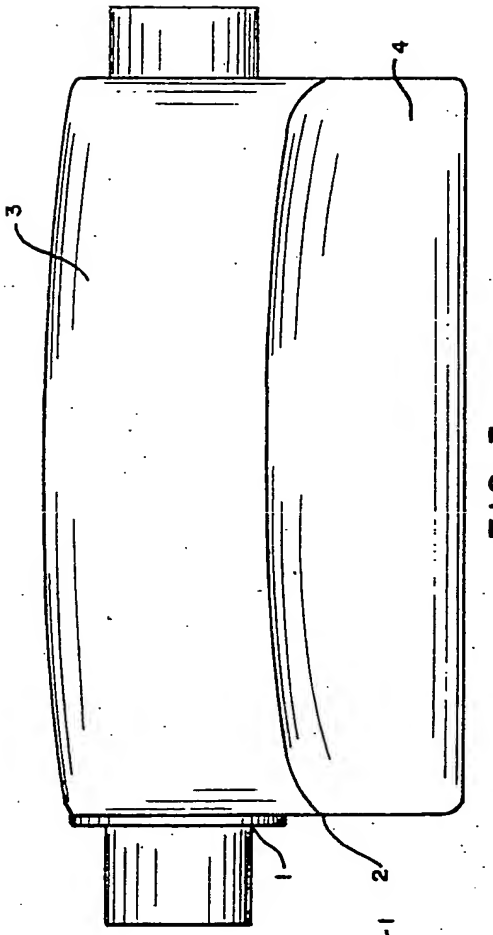

FIG. 3.

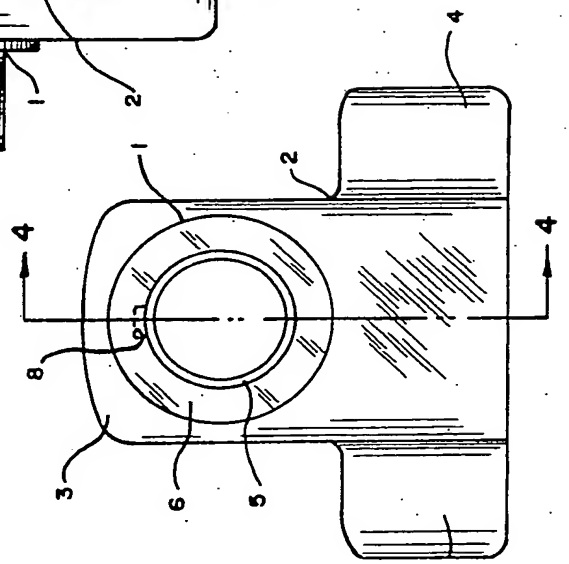

FIG. 2.

1 520 432
5 SHEETS
COMPLETE SPECIFICATION
This drawing is a reproduction of the Original on a reduced scale.
SHEET 3

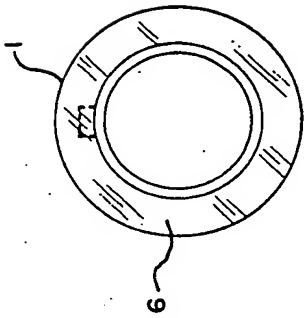

FIG. 6.

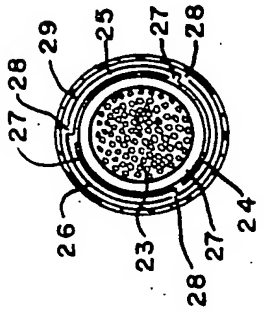

FIG. 8.

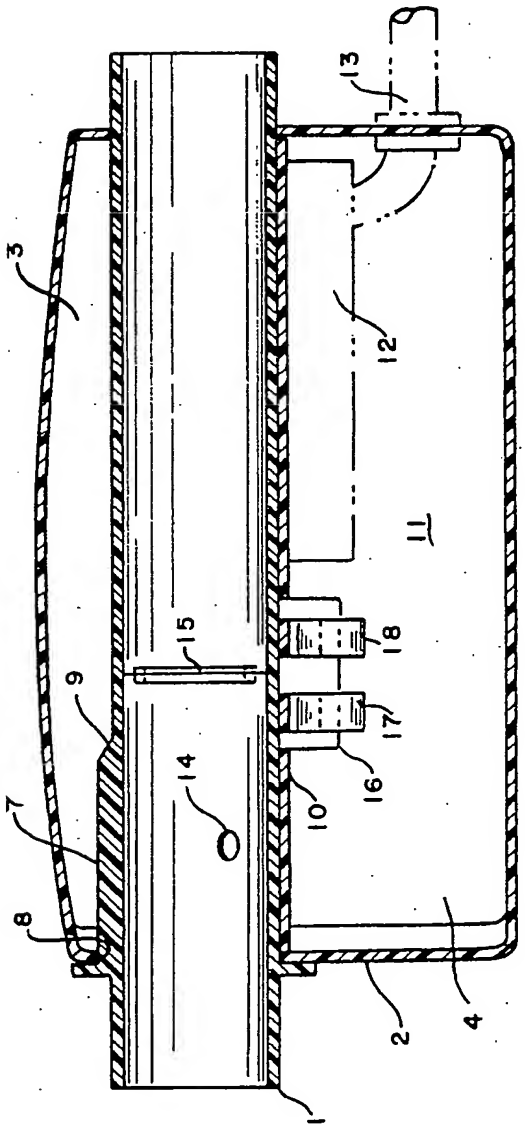

FIG. 4.

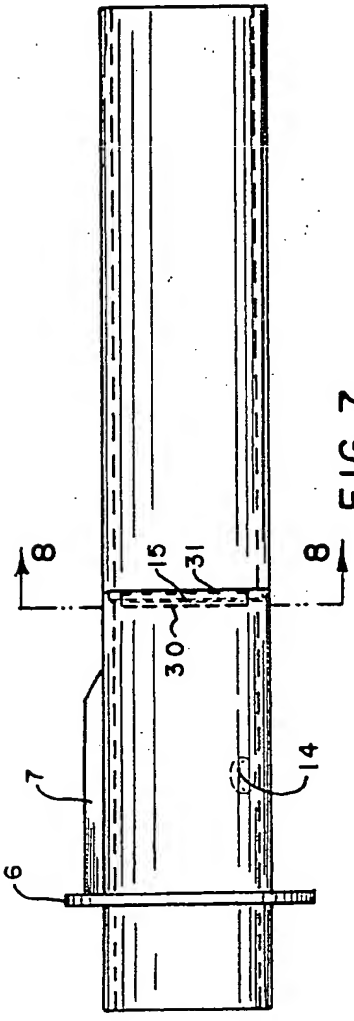

FIG. 7.

1 520 432
5 SHEETS

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.
SHEET 4

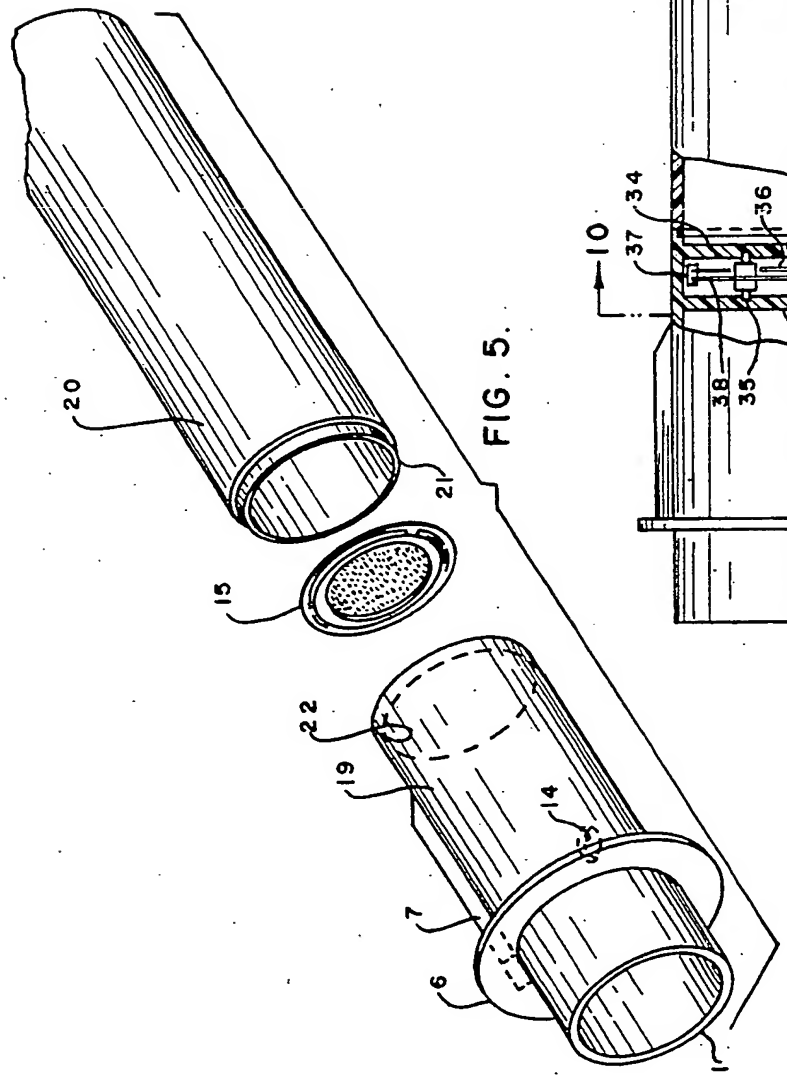

FIG. 5.

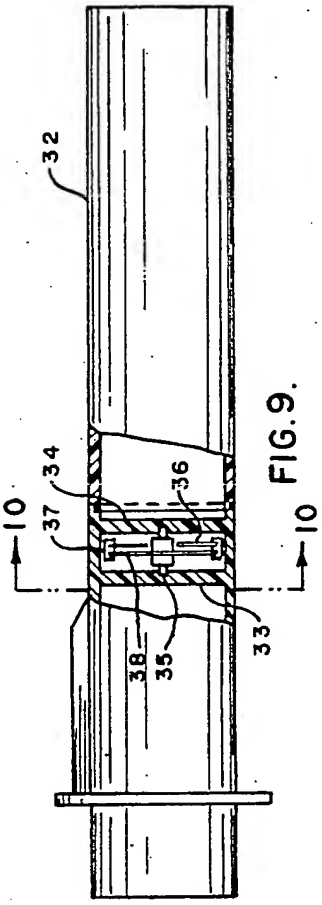

FIG. 9.

1 520 432
5 SHEETS

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.
SHEET 5

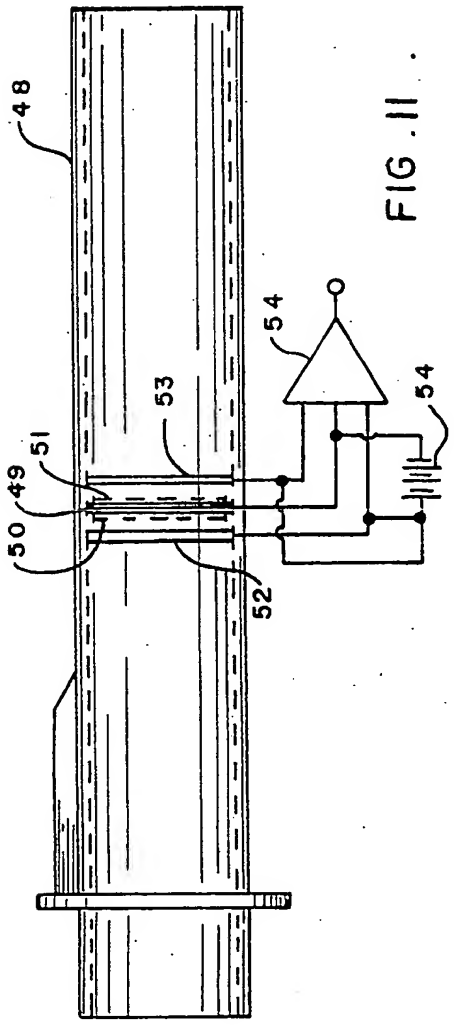

FIG. 11.

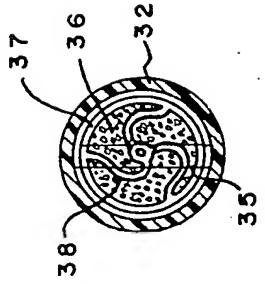

FIG. 10.